## SCIENCE AND ENGINEERING PRACTICES
### PERFORMANCE EXPECTATIONS
#### PERFORMANCE INDICATOR
**S.1B.1: CONSTRUCT DEVICES OR DESIGN SOLUTIONS**

### Grade Level Progressions

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Performance Expectations</th>
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<tbody>
<tr>
<td>K.S.1B.1, 1.S.1B.1, 2.S.1B.1</td>
<td>Construct devices or design solutions to solve specific problems or needs: (1) ask questions to identify problems or needs, (2) ask questions about the criteria and constraints of the devices or solutions, (3) generate and communicate ideas for possible devices or solutions, (4) build and test devices or solutions, (5) determine if the devices or solutions solved the problem, and (6) communicate the results.</td>
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<tr>
<td>3.S.1B.1, 4.S.1B.1, 5.S.1B.1</td>
<td>Construct devices or design solutions to solve specific problems or needs: (1) ask questions to identify problems or needs, (2) ask questions about the criteria and constraints of the devices or solutions, (3) generate and communicate ideas for possible devices or solutions, (4) build and test devices or solutions, (5) determine if the devices or solutions solved the problem and refine the design if needed, and (6) communicate the results.</td>
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<td>6.S.1B.1, 7.S.1B.1, 8.S.1B.1, H.B.1B.1, H.C.1B.1, H.P.1B.1, H.E.1B.1</td>
<td>Construct devices or design solutions using scientific knowledge to solve specific problems or needs: (1) ask questions to identify problems or needs, (2) ask questions about the criteria and constraints of the device or solutions, (3) generate and communicate ideas for possible devices or solutions, (4) build and test devices or solutions, (5) determine if the devices or solutions solved the problem and refine the design if needed, and (6) communicate the results.</td>
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### Specific Changes Per Grade
- Starting in grade 3, performance expectations expand to include not only evaluating a device or solution but also **refining the design if needed**.
- Starting in grade 6, performance expectations expand to include the **use scientific knowledge** to solve specific problems or needs.

### Defining Characteristics
Where science is the process of investigating the universe through asking questions, gathering and analyzing data, constructing explanations and models to describe phenomena, and communicating what is learned, engineering is the application of scientific principles and knowledge in the search for a solution to a problem or need. Despite these differences, the practices of engineering are analogous to the practices of science.

*The Engineering Process*
The engineering process is broken down into six component steps, each of which has an analogous counterpart in the science practices.

1. Ask questions to identify problems or needs.
   - Engineers figure out what problems or needs exist and if they are, in fact, genuine in nature, that is they are real problems and not assumed.

2. Ask questions about the criteria and constraints of the devices or solutions.
   - Engineers further investigate the nature of the problem or need they are attempting to solve in order to identify what scientific concepts will be applied, what limitations and constraints might affect the design of a solution or device, and what other parameters need to be accounted for in solving the problem or need.

3. Generate and communicate ideas for possible devices or solutions.
   - Engineers design and communicate proposed devices or solutions that they predict will address problem or need as defined by the identified constraints and criteria.

4. Build and test devices or solutions.
   - Engineers build and test full-scale prototypes or models of prototypes of devices that will meet the need or solve the problem. In the case of solutions, engineers test their proposed solutions or tests their solutions through the use of models. In both cases, the intent is to gather data to evaluate the effectiveness of their design.

5. Determine if the devices or solutions solved the problem and refine the design if needed.
   - Engineers analyze and interpret the test data to determine if their devices or solutions solved the problems or met the needs. If necessary, devices or solutions are refined based on the analysis of the data and tested again.

6. Communicate the results.
   - Engineers communicate the results of their design tests, using evidence to support claims that their design was effective at solving the problem or meeting the need.

The following table illustrates the relationship between the practices that scientists engage in and the practices that engineers engage in. Because these eight practices are analogous to one another and have already been described in detail in other sections of this work, that information is not reproduced here.

<table>
<thead>
<tr>
<th>What Scientists Do</th>
<th>What Engineers Do</th>
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<tbody>
<tr>
<td><strong>Ask Questions</strong>: Scientists ask questions about unknown phenomena in order to investigate and develop an understanding of the natural universe.</td>
<td><strong>Define Problems or Needs</strong>: Engineers identify problems or needs in order to design, test, and refine possible solutions.</td>
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<tr>
<td><strong>Develop and Use Models</strong>: Scientists develop and use models as a means to test and manipulate and communicate how natural phenomena and processes occur.</td>
<td><strong>Develop and Use Models</strong>: Engineers develop and use models both to test and refine possible design solutions as well as to communicate successful designs.</td>
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</table>
### Plan and Carriy Out Investigations:
Scientists plan and carry out investigations as a means to acquire data, both observations and measured, about natural phenomena.

### Plan and Carriy Out Tests:
Engineers plan and carry out tests of proposed solutions and design in order to evaluate the efficacy of their designs.

### Analyze and Interpret Data:
Scientists analyze and interpret data acquired through investigation and experimentation in order to look of patterns, trends, outliers, etc… that can help determine a cause and effect relationship of a natural phenomenon or process.

### Analyze and Interpret Data:
Engineers analyze and interpret data acquired through tests of proposed designs or solutions in order to determine if their designs or solutions are successful at meeting the need or solving the problem.

### Use Mathematics and Computational Thinking:
Scientists apply math practices as part of the analysis and interpretation of data. Computational tools and thinking include the use of technologies, practices, and models to represent and manipulate complex, large data sets.

### Use Mathematics and Computational Thinking:
Engineers apply math practices as part of the analysis and interpretation of test data. Computational tools and thinking include the use of technologies, practices, and models to represent and manipulate complex, large data sets.

### Construct Explanations:
Scientists use evidence from investigations and scientific reasoning to construct explanations for natural phenomena and processes.

### Design Solutions:
Engineers use evidence from design tests and the application of scientific principles to design viable solutions to problems and needs.

### Engage in Scientific Argument from Evidence:
Scientists engage in scientific argument as a process of analyzing and interpreting data and apply scientific reasoning in making claims supported by evidence as well as analyzing alternate conclusions supported by data.

### Engage in Argument from Evidence:
Engineers engage in argument as a process of evaluating the efficacy of proposed solutions or designs as well as evaluating alternate designs and solutions to problems or needs.

### Obtain, Evaluate, and Communicate Information:
Scientists obtain scientific information to provide context for everything else they do. They evaluate sources of information, whether from texts or data, and they communicate information, claims, explanations, and models.

### Obtain, Evaluate, and Communicate Information:
Engineers obtain scientific information in order to apply scientific principles and concepts throughout the design process. They evaluate information use to support their designs as well as test data, and they communicate their designs through claims, proposals, and models.

For more details about the defining characteristics of each component of this practice, refer to the support documents for the specific practices identified above.
It is important to understand that science and engineering are not separate sets of practices. It is through the application of scientific concepts and principles that engineers determine the nature of human needs and problems, evaluate the criteria and limitations of problems and possible solutions, and ultimately develop solutions and devices that apply scientific concepts in a concrete manner that is used to solve problems and fulfill human needs. This is why performance indicators related to engineering are embedded within science content strands.

The goals for this practice are for students to apply scientific concepts and ideas to the solving problems or meeting needs. Students should define problems related to scientific concepts, design and test devices or solutions, and model and propose successful devices or solutions that reflect both an understanding of the underlying scientific concepts under study as well as how those concepts are applied in the solution of a problem or the design of a product that meets a need.

INSTRUCTIONAL GUIDANCE AND CONSIDERATIONS

Scope and Sequence: When to introduce an engineering challenge

Teachers should be aware that engineering performance tasks are likely to take a greater amount of instructional time to complete. Therefore, engineering problems are best introduced at the beginning of a unit of study. As the students learn about and investigate the science content developed in the unit of study, the teacher will direct them back to the engineering problem and how their new information might be applied to solving the problem or designing a solution. In this way, the content of the standard is appropriately addressed while the engineering performance indicator provides an authentic context for the application of the science concepts and understandings. Teachers who wait until the end of a unit of study to then introduce a design challenge as a project-based learning experience will find that their students will not have the time necessary to complete the task before the teacher needs to move on to the next unit of study.

It is essential for student to

- Understand that technological designs or products are produced by the application of scientific knowledge to meet specific needs of humans. The field of engineering focuses on these processes.
- Understand that there are four stages of technological design:
  - Problem identification
  - Solution design (a process or a product)
  - Implementation
  - Evaluation
- Understand that common requirements within the solution design stage of all technological designs or products include:
  - Cost effectiveness or lowest cost for production;
  - Time effectiveness or the least amount of time required for production
  - Materials that meet specific criteria, such as:
    - Solves the problem
    - Reasonably priced
• Availability
• Durability
• Not harmful to users or to the environment
• Qualities matching requirements for product or solution
• Manufacturing process matches characteristics of the material

- Understand that benefits need to exceed the risk.
- Understand that there are tradeoffs among the various criteria. For example, the best material for a specific purpose may be too expensive.
- As the various components of this practice have been described elsewhere in terms of defining characteristics, instructional guidance, performance expectations, assessment tasks, etc., that information will not be reproduced here. Details for instructional guidance and considerations can be found for each subdivision of this practice in the support document for each specific practice.

### EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Define problems and needs.
- Describe the criteria and limitations of a problem or need.
- Design and propose possible solutions based on scientific thinking.
- Test designs/solutions.
- Analyze test data to determine if the design or solution was successful.
- Refine designs if necessary based on the outcome of design tests.
- Support claims made about designs based on evidence and scientific reasoning.
- Propose and communicate successful designs/solutions.
- Analyze and evaluate the designs/solutions of others.

### PERFORMANCE TASK EXAMPLES

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples is to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.
<table>
<thead>
<tr>
<th>Grade</th>
<th>Subject</th>
<th>Example</th>
<th>Non-Example</th>
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<tbody>
<tr>
<td>K</td>
<td>Earth Science</td>
<td>Students plan an outdoor celebration. They define problems related to weather that might occur with an outdoor activity. They ask questions about possible constraints and criteria that will affect and/or limit possible devices or solutions. They brainstorm and communicate possible solutions or devices that can be used to solve the identified problems. Students then test devices or models of devices and/or justify solutions to weather-related problems. They analyze results of tests to determine if the solutions/devices solved the problem. Finally, students communicate the results.</td>
<td>Students identify possible problems from a given list and pick a solution from a prescribed set of possible solutions. Students justify the solution the teacher proposed. Teacher tells students how problems like this are solved.</td>
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<tr>
<td>3</td>
<td>Physical Science</td>
<td>Students are informed that their local zoo is going to build a new habitat for their penguins. Assuming the role of habitat designers, students ask questions about the problems or needs related to maintaining an ideal temperature in a penguin habitat. Students ask questions about criteria and constraints related to the design of a new habitat. Students generate and communicate ideas for possible habitat designs and build and test model habitats to acquire evidence needed to determine if the proposed habitat design is effective. Students refine their designs as necessary. Students communicate results.</td>
<td>Students are given a set of predetermined materials with instructions to build a model penguin habitat and will test predetermined outcomes. Teacher will provide an article about penguin habitats that students will read and discuss the article in terms of effective design.</td>
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<tr>
<td>High School</td>
<td>Biology</td>
<td>Students research topics related to human impacts on the biodiversity of an ecosystem. Based on their research, students generate questions about ecological problems related to the human impact on biodiversity. Students also ask questions about the constraints of possible solutions to human impact. Students generate and communicate ideas.</td>
<td>Students build an ecosystem diorama. Students read about human impact on biodiversity and write a report or presentation to their class. Students tour immediate school ground to identify ecosystem components and local biodiversity.</td>
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for possible solutions to minimize the impact of human activities on biodiversity of that ecosystem. Students justify their proposed solutions, supporting claims with scientific evidence from research and models, refining their solutions as needed. Students communicate their solutions as part of a proposal to minimize the human impact on the particular ecosystem.